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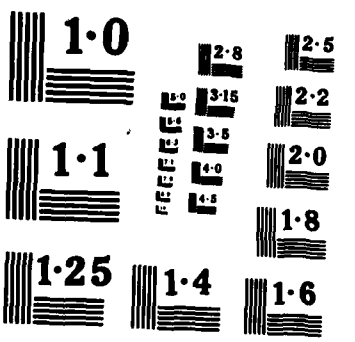
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ONRL Report

Present Status of Physics Research in Spain:
Some Impressionistic Remarks

Paul Roman

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U.S. Office of Naval Research, London

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PRESENT STATUS OF PHYSICS RESEARCH IN SPAIN: SOME IMPRESSIONISTIC REMARKS

1 INTRODUCTION

Need for and Purpose of This Report

When monitoring scientific life and reporting on progress in Europe and the Middle East, there is an unmistakable tendency to focus on the more developed, highly industrialized countries. But rapidly developing countries often offer many surprises in all social and intellectual areas. Conditions and performance factors of research are no exception. Unfortunately, the American scientific community very often gets a slanted picture. There are several reasons for this. First, researchers generally follow developments only in their own specialty. Second, the sociology and politics of international scientific interactions are such that researchers in the leading countries usually will be in contact only with the very best, most favored, and "smartest" colleagues from abroad (where "smart" is meant to have several connotations). Third, there still is an unfortunate insularity in the present influential generation of US scientists: much of their interest is in Anglo-Saxon literature, which again limelights only a special subclass of scientists of less developed countries (and discourages the emergence of a respectable local scientific literature in other languages). As a consequence of these factors, fledgling and support-deserving efforts, as well as big gaps in coverage of topics or lack of progress, can be easily overlooked by the US scientific community. But in an age when international cooperation in frontier areas and in applications becomes more and more the concern of defense-related policy bodies in the US, a broader view and understanding of the picture in less-known yet talent-rich countries become a necessity.

The purpose of this report is to provide a minor contribution to the alleviation of such problems.

Origin of This Report

When I was preparing for a trip to survey some areas of physics research in Spain, CAPT Harry H. Burks (Defense Industrial Cooperation Affairs Officer, Chief, Navy Section, JUSMG-MAAG, Madrid) asked that I send him, after my trip, a summary of my experiences. Actually, he asked me the point-blank question, "Are the Spanish doing anything new or just re-proving what others have already done?" With many reservations, I answered this question in the negative in a letter report to JUSMG-MAAG, dated 29 January 1985, but I find it worthwhile to elaborate on some details and make this document available to a broader readership.

Cautionary Remarks on Background

I spent only a short period (8 through 23 January 1985) in Spain, visiting Madrid and Barcelona, and concentrating mainly on research in optics (particularly quantum optics), some solid state physics, microelectronics, nonlinear dynamics, theoretical physics, and the expert-system aspects of artificial intelligence. I visited 10 institutions and talked to about 15 senior people, as well as to a smaller number of younger researchers. Thus, my coverage of facts is necessarily superficial, limited, and more impressionistic than scientific. On the other hand, with the help of some old personal friends and new acquaintances, I was able to elicit very uninhibited and frank (but perhaps personally tinted) responses to queries that went beyond the scientific reporting work which was my main task.

Apart from the usual contacts with physics department heads and institute directors, I found three officials (not well known in ONR circles) particularly knowledgeable and keen on establishing relations: Dr. Carlos Angulo Carranza, Special Professor of Telecommunication at the Polytechnic University of Barcelona, recently detailed to become a Deputy Director of CSIC in Madrid; Dr. Ramon Pascual, Professor of Theoretical Physics at the Autonomous University of Barcelona and Director of GIFT, also member of Ministerial Committees on the improvement of physical sciences; and Dr. Manuel G. Velarde, Professor of Physics at UNED ("Open University"), Madrid, and one of the most vocal members of many governmental committees on reform.

2 PRESENT STATUS OF RESEARCH

Available Background-Information Materials

The Organization for Economic Cooperation and Development (OECD) publication, "Science and Technology Indicators: Resources Devoted to R&D" (Paris, 1984), places Spain in the category of "countries giving little or no priority to R&D" and surveys some aspects of its research together with those of Portugal, Greece, Iceland, and Turkey. From what I saw, I would tend to agree with the OECD statement that "the efforts to apply the recommendations of the various ministerial meetings have often never left the theoretical state....Certain reforms ... are still under way, without reaching any tangible results....The administrative machinery does not itself ... facilitate the establishment of desirable science policy." However, these criticisms of procedural mispractices do not justify a dismissal of both current and potentially near-future achievements. Indeed, James W. Daniel, correctly sounded a more positive tune in his article "Spain's Research Fund Small But Growing" (*ESN* 38-6:336-338 [1984]). This article is good general-background reading on the structure of the Spanish research organization, and I give here only a brief summary of science agency profiles.

The Ministry of Education and Science (MEC) has a double function: it is responsible both for education on all levels and for research support in general. One of the troubling features is that most of MEC's resources are committed to educational policy and practice.

MEC is responsible both for university research as well as for the numerous independent government research centers that form part of the Consejo Superior de Investigaciones Científicas (CSIC), which, despite its name (supreme council of scientific investigations), cannot be likened to the US National Science Foundation (NSF) or to the President's Office for Science and Technology; it is rather like the West German Max Planck Gesellschaft (except that it has neither regional nor private funds).

Decisions about fund allocations (to university research groups, to the CSIC, and to some private industrial research, of which there is very little) are made by the Comisión Asesora de Investigación Científica y Técnica (CAICYT), which is an interministerial body closely tied to the Dirección General de Política Científica and MEC. The CAICYT is also responsible for some of the infrastructure support, such as funding of major national or regional instrumentation or equipment. The total available funds of CAICYT in 1984 amounted to about $48 million. (No breakdown into research areas is available to me.) An interesting feature of this powerful body is that its executive councils now contain rotating members from both the CSIC and the more prestigious university departments.

Another important figure to remember is that the total CSIC budget for 1984 was $59 million (note that most of this comes as direct-line items from MEC and a smaller part from CAICYT grants); of this total $4.6 million went to physics, but the technology and engineering institutes' $9.6 million budget also contains many physics research items. (For comparison, it may be worth noting that the biological, biomedical, and food sciences received a total of over $13 million.)

My personal judgment on these figures is that, while not generous, the centralized fiscal support for physics is adequate--the problems lie elsewhere.

One last piece of documentary material should be discussed before I turn to more personal observations. A booklet entitled "La Física en España" was published by the CAICYT in 1982. Unfortunately, even then it was already somewhat dated because it is based on a study by a distinguished committee during the 1979-80 academic year. Moreover, as far as I can judge, the committee's data-gathering and evaluating mechanisms were rather amateurish and maybe even self-serving. On the other hand, I have discussed the major points of this document with several trustworthy colleagues and was assured that most of the facts are still valid even

though the numerical data changed for the better.

Here then, are the salient points of this survey.

The committee members assumed that problems in the discipline of physics stem from a general neglect of research. They pointed out that Spain invested in 1978 only 0.3 percent of its gross national product for all R&D (today the figure is probably around 0.5 percent). This is certainly below the corresponding data for Italy and even Yugoslavia. The report hastens to point out that physics is in no way better off in support than are other sciences (but my informal discussions and some recently released data do not necessarily support this view). In any case, the report correctly points out that scarcity of funds has led to an imbalance inasmuch as there is a larger development in theoretical physics and in low-resource-intensive experimental physics than in other areas which, pragmatically, should develop faster. (To the surprisingly well developing areas I would add the field of computer science and especially artificial intelligence.) A further finding of the survey was that there are about 27 active research physicists per million population in the country (which is about the same ratio as in, say, Hungary between 1940 and 1956). Most of them are in the Madrid area, working for universities and CSIC institutes, while the number of industrial research physicists (not including production-line, quality-control engaged physicists) is practically nil. (There was some improvement in this area during the past 2 years.)

A survey of the distribution of research physicists showed that theoretical physics (mainly particle theory), solid state physics, and molecular physics have the highest numbers of researchers. (This is still unchanged.) Electromagnetism and electronics was (and partly still is) relatively underpopulated, and optics, which was in quite good shape even at the time of the survey, made spectacular progress, as I could well observe. Nuclear physics was (and is) weak; but again, mechanics and thermodynamics, classified unsatisfactory in the report, picked up remarkably by going into much interdisciplinary work, including nonlinear dynamics and phase transitions--even though most is still done only on the level of theoretical physics and applied mathematics.

The survey placed considerable emphasis on the fact that in the 1950s and 1960s, when physics was building up, a very large number of young physicists went abroad to complete their training and obtain terminal degrees. The picture started to change in the mid-1970s, and I have been assured that by now only a negligible fraction of Spanish physicists get their PhD degrees abroad. (On the other hand, I observed that an increasing number of young and even more mature physicists go these days to work in France, West Germany, Italy, the UK, and the US as post-doctoral research fellows.) The survey pointed out (and I think this holds even more today) that these pre- or post-doctoral extended stays in foreign laboratories often lead to continued collaborations. Personally I think that--with some reservations, to be described below--this is a good thing and aids the modernization and rapid development of Spanish physics.

It may be appropriate to inject at this point the rather recent policy plan (to my mind perhaps more sloganistic than realistic) which wishes to emphasize much stronger relations, both in education and in research, between Spain and Latin America. Most colleagues I asked about this responded by saying that Latin America is far, Europe is near.

A Kaleidoscope of Personal Observations

With the official and formal background out of the way, I would like now to concentrate, in a not very systematic manner, on qualitative features of some sectors of Spanish physics research which struck me in one way or another as unusual.

An Amazing Unevenness of Levels and Efforts

To start with, I must say that the status of the fields I have seen (and by probable extension, of other fields in

physics as well) is incredibly uneven. In some areas certain topics have never been considered at all, and in some other areas--well taught at the universities and represented by specialists--no research is done. In some other areas reasonable, routine work has been going on for quite a number of years now, but it progresses very slowly, without breakthroughs that could have been expected from the (admittedly modest, but ongoing and steady) support over the years. Yet in other areas I found *isolated* individuals, sometimes even small groups, doing pioneering work comparable to anything I have seen so far in Europe. Much of this work is good enough to be published in the US, and earns the researchers well-justified invitations to international conferences and renowned institutions. In addition to these extremes, I also found one more type of effort: places where pioneering research is being planned and which are going through a transitional period. At such institutions or departments, groups of people (including students) are vigorously and rapidly trying to acquire contemporary methods and techniques. In these places, of course, the visitor will get the impression that the scientists are repeating things which have been done elsewhere; but I think this is a necessary intermediate stage, and even during the learning period it often happens that fine original ideas are being put forward.

I found an amusing illustration of this mix of levels in development at a well-known CSIS institute, where on one floor people worked on basic research relevant to optical memories, surface modification, and thin film studies, and had access to absolutely up-to-date equipment (although they could not run all their computers simultaneously because of inadequate power lines). On another floor, routine but developing work was done (with partly modern, partly homemade, shaky equipment) on interferometry and image processing. And in the basement, an ancient, rickety setup was used to do (redo) Michelson-Morley experiments in new versions.

Closely related to the observations made in the preceding two paragraphs is the astonishing fact that, despite the generally low level of funding and its unevenness, the proportion of high-quality papers published per number of active researchers is significantly higher than one would expect. (It is impossible to get hard data in this area, but even the strongest critics of Spanish physics, including colleagues from industrially developed European countries, generally assert this fact.) I think that these outstanding results come about by the dedicated work of highly qualified, very ambitious *individuals*. These people are first-class scientists but great individualists. For some reason or another they do not manage, or perhaps do not care to build up a group. They work hard, enjoy their exalted status, travel abroad quite extensively, and publish in highly respected international journals. By consensus of their departmental colleagues, such "stars" often manage to concentrate all their teaching obligations into one semester and take off the other semester, usually to work abroad (and sometimes just to be able to do leisurely research at home). Many of these unusual top scientists, while not building up versatile and mixed research groups, do have a few doctoral students whom they consider "cheap labor" and do not entice to stay on after they receive their degrees. The problem of many top people not making an effort to organize a "school" around themselves is a serious one, and must be addressed in some way. Of course, there are notable and encouraging exceptions. I found two good "schools," one in Madrid and one in Barcelona. In each case, there was a dedicated leader who knew how to arrange for cooperation between government, university, private sources, and even foreign granting agencies, and who inspired a number of people to stay within the group for extended periods and build their careers *within* the group. Unfortunately, these are exceptional cases.

The New University Reform Law and Some of its Consequences

Other serious, but maybe only transitional, structural problems in the area of university research were

created, ironically, by the recent Law for University Reform. This was pushed through Parliament, after lengthy preparations and competing legislative proposals, in an unseemly rush by the Socialist party in 1983. From the point of view of this report, it has three salient features. First, it defines the university as a public service, proclaiming that higher education is a right of everyone who wishes to pursue it. Thus, while the law states that it is intended to help universities to achieve their objective "of scientific development, the education of professionals and the spreading of culture," the emphasis is on mass education of uneven quality--somewhat like in the current SUNY system of New York State. Second, the law reaffirmed the civil servant status of professors, but drastically reduced the proportion of allowable fixed-term contracted teaching staff (who were not civil servants). The many categories of professorial status have been abolished, and in the future there will be only "titular" professors (essentially on the level of our associate professors) and "catedráticos" full professors. (In contrast to the past, a department may now have several catedráticos, with, of course, reduced power and influence.) In principle, the cumbersome system of exams necessary for promotion to tenured professorial status has been abolished, and selection may be made on the basis of resumes and recommendations (also, "connections" count a great deal). In practice, exams for becoming permanent staff are still going on in a modified form. The third important change heralded by the new law is that the government is supposed to transfer some control of a part of the universities to the more-or-less autonomous local governments of the different regions of Spain. This process already has been put into effect in Catalonia, so far with mostly positive results, as one might expect to be the case with any kind of decentralization.

Now let me comment on some consequences of these major features of the university reform law.

Even before this law was enacted, some of the major universities began to grow to unmanageable sizes. The reforms accelerated this negative process. For example, the major university in Madrid (Universidad Complutense) now has approximately 125,000 students and several thousand instructors. (There are several other big universities in Madrid; the biggest "overflow" institution [the Autónoma] counts 40,000 students.) The teaching duties at these mammoth institutions are overwhelming. In addition to the obvious restrictions that this size places on the time instructors have for research, it is also clear that the sheer maintenance of such big universities leaves very little money from the operational budget to go for research or even for the modernization of general equipment. The most shocking example I saw in this regard was the extent of computer support for all academic and research work at the Universidad Complutense in Madrid: all they have (besides scattered microcomputers) is a single, 15-year-old IBM mainframe computer which has not more than 10 computer terminals (with video displays) and only two printers. Most of the work is still done by batch processing.

A second, very confusing effect of the university reform is that each university is now required to work out new statutes and bylaws that must conform to the new regulations. This task is done by General Assemblies (with subcommittees), and at this point a tremendously threatening development is occurring: the Communist unions are taking over more and more universities. Apart from the generally known negative effects of unionization of universities, here we face a more specific danger: because of the unions' power, often no more than one-third of the members of the reform committees (as well as any other committee) have faculty rank; the rest are students, secretaries, and janitors. It is hard to see how rational decisions on the improvement of research conditions and future research development can be achieved under such circumstances.

A third negative effect of the reform laws is the increasing concentration of university research in Madrid. This has been going on for quite a while, to the detriment of smaller provincial universities, which sometimes, in special fields, had fine research work in physics. Because of the redistribution of professional positions and new openings arising in big institutions, the reform laws accelerated this process. Even Barcelona lost a number of fine researchers to Madrid. Clearly, the best people make an all-out attempt to get catedrático positions in Madrid--while it is still possible to obtain a powerful leadership position in a prestigious place. In one case, an outstanding leader in optics, who had both a strong group going and controlled fine equipment in Zaragoza, was called upon to head the most prestigious university optics department in the country, which of course is in Madrid. As a consequence of his move, his Zaragoza group dissolved within a couple of years, and the assembled modern equipment fell into disuse. Of course, this fine gentleman is now building up a similar but larger group in Madrid, but this will take quite a time.

There is a fourth, and largely, but not exclusively, positive effect of the reform laws. At the present time, university physics research is done in an extremely fragmented format. One would find at the faculty of sciences departments such as general physics, experimental physics, theoretical physics, solid state physics, physics of materials, statistical physics, optics, and electro-physics, each with a full professor as head, an independent budget--and often only a couple of members. There is generally little cooperation between the physics mini-departments, even though people know each other well from committees (which often cut across universities) and from professional societies. The new law strongly opposes this fragmentation--but it may bend over backwards. For example, it attempts to legislate by fiat a minimal size for departments (12 professors, titulares and catedráticos, is the prescribed minimum) and a regrouping according the lines of knowledge-area-classifications as set up by MEC.

The Government Research Institutes

There is a marked difference in the style and often in the quality of research done at the universities and at the specialized CSIC institutes. Surprisingly, these research centers were founded and built up in the early 1940s, immediately at the termination of the disastrous civil war. These special-purpose institutes carry out both basic and applied research. Generally speaking they have better equipment, more up-to-date instrumentation, and certainly less harassed researchers than the universities have. Research groups form more easily and develop well, although one finds a proportion of "deadwood" from the olden days, too. Graduate students are permitted to work on their PhD thesis at these institutes (but receive their degree from some university).

The CSIC institutes also have a number of problems. For example, there is practically no cooperation between them and university departments, even though both are funded from the same ministry and employees at both institutions are civil servants. There are exceptions: aggressive leaders occasionally manage to charter an institute that is cosponsored by a university and the central CSIC administration (for example, the Instituto de Cibernética in Barcelona).

The CSIC institutes must also cope with political burdens. Despite the fact that the new law promised increased budgets, in actual fact most of the budgets have been curtailed in the past 2 years, and some of the institutes lost part of their influence. Apparently, I was told, the current Socialist government looks at the CSIC with some suspicion because it was founded (and partly staffed) during the Franco era.

There are various plans talked about for a forthcoming change in the structure and role of the CSIC. It is possible that if this indeed becomes a reality, it will strengthen the links between government, university, and industry research.

Some Examples of Promising Developments

While shortcomings are easy to detect and are brought home forcefully to a visitor by his less fortunate fellow scientists, it is important not only to mention general assets and positive trends (~~as I attempted~~ to do above) but also to highlight specific examples of promising new events.

One of the most interesting recent developments I saw was an ongoing, concentrated, and well-coordinated effort which aims to build up a very significant Spanish research base in the area of microelectronics. This national project involves two CSIC research institutes (one in Madrid, one in Barcelona); several universities; the official Spanish telecommunication organization (Telefonico); and America's AT&T. Other local, small-scale private industry is expected to join the project. This is important because, as I already hinted, at present there is hardly any research going on in industry (probably because most high-tech firms are subsidiaries of foreign, primarily American or Japanese, companies, and simply import the know-how from the mother firm). Many leading scientists told me that the project is backed by strong determination and generally expected to succeed. Moreover, they were confident in predicting that the success of the project will serve as a model for other such concentrated efforts in different areas. Indeed, there is already broad-based cooperation involving theoretical, experimental, and technological aspects of high-energy physics; this effort emerges through a strong liaison with CERN, the European Center for Nuclear Physics Research. Another cooperative program between 13 university departments, about 16 industrial firms, and a CSIC institute focuses on photovoltaic conversion of solar energy. The ultimate goal is to build a 100-kWh modular photovoltaic generator. Finally, I saw well-organized efforts to build up both the basic science and application aspects of artificial intelligence and robotics. It may be worthwhile to observe that most of this latter effort is financed and coordinated not by the central government but by the local Catalan authorities. Perhaps this may become a trend.

Next I want to give an example which shows that the organizational difficulties that bedevil university research are not unsurmountable, and that dedicated, resourceful, self-reliant leaders have a good chance for success. I observed this particularly well at the Instituto de Cibernética in Barcelona. As I mentioned above, this institute originated in 1975 by the merger of a section of the computer science department of the Catalan Polytechnic University and a special-purpose research institute of the CSIC. It has now considerable independence and performs both large-scale educational and broad-based research functions. The deputy director, who is in charge both of research and structural development, is not only a first-class expert but also a scientific leader and gifted personnel manager who knows how to attract good faculty, associates, students, post-doctorals, and a flow of visiting scientists. He also found ways to make individual "deals" with local industry and public services, solving problems for them in return for their giving equipment for the permanent, sole use of the institute. For sake of illustration, let me point out that, apart from having priority access to the Polytechnic's mainframe computer, the institute now has two dedicated, high-power, up-to-date VAX computers, sophisticated image processing and graphics systems, and even a first-class hybrid digital-analog computer system with two smart workstations. (Contrast this with the computer situation at Madrid's Complutense, referred to earlier!) In addition, he managed to obtain grants not only through the CAICYT but also from extragovernmental sources, including one from the NSF. Of course, this way of operation is precisely the "tripartite" model of the new type of university research management which we in the US have advocated for some time now. I am sure there are very good chances in Spain for this system to work.

3 EVALUATION AND RECOMMENDATIONS

Because of the impressionistic character and primarily short-term-based personal background of this study it is not advisable to make a scholarly summary. But I would like to point out that even though a first reading of this report will tend to attract attention to difficulties and shortcomings, it was not my intent to create a negative final impression.

Perhaps the major point to note is that physics research is not "backward" and that the substantial difficulties are the consequence of an overcentralized, bureaucratized, overpoliticized infrastructure and not of the lack of talent and willpower. While it is true that Spain's great traditions lie more in the field of the humanities than of the sciences, in our strongly interdependent and interacting modern world this cannot be a serious factor in the consideration of future development.

Despite the somewhat unstable political background of the country, it appears that the urgent need to reorganize the structure of research and development, as well as to find better ways to distribute R&D funds, is a genuinely and generally felt need of all concerned parties. There will be more false starts, but even now the way is not entirely shrouded in darkness.

More and more responsible leaders feel that it would be well advised to abandon over-ambitious aims (such as fusion energy research), refrain from covering entire fields, and instead concentrate on selected projects. In *Some Examples of Promising Developments*, above, I described one of these, the microelectronics project. Apart from the scientific justification (related to the multidisciplinary nature of the studies), proponents of this project pointed out to me one other interesting aspect. True, they say, Spain has little chance to become a leader in this area or even to compete successfully with industrial giants. But in order to be competitive in the economic area of non-high-tech industries and to be able to sell modern products in the fields such as motor cars, household appliances, simple communication equipment, cameras, and toys, it is still necessary to develop a national microelectromics base--otherwise the country would inevitably slip into the status of one with a colonial economy.

Related to the last comments is my sense that Spanish science would benefit greatly if the country could join the European Economic Community (EEC), which recently instigated a number of, admittedly imperfect but promising, science- and technology-furthering projects (for example the ESPRIT program in computer science). Similarly, a clear-cut positive solution regarding Spain's NATO membership would be a bonus to scientific development and would surely not be a one-way road. Even though these are sophisticated political questions, we should not ignore them (and our possible role to help) when contemplating development of science.

I believe that Spanish physical science, both in basic and, to a lesser extent, applied areas, has passed the stage of infancy and has truly great potential. We should support it in a *selective* way. By this I mean not only a choice of research areas, but also a careful selection of institutions and people. We should focus on outstanding individuals and their groups--those who are not playing their own ego-trip game but who are sincerely dedicated to building up future strength in their area, for the benefit of the country. These selected individuals should also have managerial-political skills and leadership qualities. Individual support to however talented people without such personal attitudes and skills would be wasteful.

Finally, some politico-economic process should be used to persuade some of the really big US high-technology firms with branches in Spain to build up true research labs in that country. They need not fear of staffing problems; considerably more well-trained PhDs are produced in physics than can be reabsorbed by academia.

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